EFFECT OF THREE END POINT TEMPERATURES ON THE DONENESS AND PALATABILITY OF PORK LOIN ROASTS

by

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INTRODUCTION

There is no accurate, quick method of inspection that detects Trichinella spiralis in infected animals. Consequently, cooking fresh pork to the well-done stage (185°F) has been the common practice to assure destruction of Trichinella spiralis and prevention of trichinosis in man. The literature indicates that for studies on cooked pork (Child, 1938; Satorius and Child, 1938; Noble and Hardy, 1945) end point temperatures of 183 to 185°F have been used. As recently as 1964, Peckham (p. 271) wrote that pork should be cooked to 185°F. However, as early as 1919, Ransom and Schwartz found that live Trichinella spiralis was destroyed by cooking to an internal temperature of 55°C (131°F). Destruction of the organism occurred at 50°C (122°F) if the larvae-infested muscle was held at this temperature for 1 1/2 hr.

The most recent Regulations of the Meat Inspection Division (MID), USDA (1960, p. 106) state that all parts of pork muscle tissue, especially the innermost parts of massed products such as sausage links, not commonly cooked prior to serving, must be heated to a temperature not lower than 137°F (58.3°C). Also, Frazier (1958, p. 408) wrote: "The chief method for the prevention of trichinosis is the treatment of pork (or other meat) to ensure the destruction of any trichinae that may be present. This can be accomplished by (1) the thorough cooking of all pork so that every part reaches at least 137°F (58.3°C)...." Thus, as pointed out by Webb et al. (1961), it appears that the currently recommended margin of safety for cooking pork is considerably more than necessary.

Webb et al. (1961) found that tenderness and juiciness scores for pork loin roasted at 176.6°C were reduced as the internal temperature was increased from 65.6 to 85.0°C. Flavor scores, cooking time, and cooking losses were increased as the internal temperature and cooking time were increased.

Weir et al. (1963) reported that pork loin roasted to 170°F had greater cooked meat yields, and received higher juiciness scores, but lower odor scores than roasts cooked to 185°F.

Limited data were found in the literature concerning the effects on pork of internal temperatures lower than 185°F (85°C), but higher than 137°F (58.3°C). Therefore, this study was designed to investigate the effect of 3 end point temperatures, 65, 75, and 85°C (149, 167, and 185°F), on the palatability and certain related characteristics of the longissimus dorsi (LD) muscle of pork loin roasted at 350°F, and any differences that may occur among sections of the loin.

REVIEW OF LITERATURE

Trichinosis

Auerbach (1960, p. 180) stated that trichinosis is caused by the parasite Trichinella spiralis, which is a thread-like worm belonging to the nematode group. Schmid (1957, p. 228) explained that after ingestion, the encysted larvae are liberated by protein digestion. The larvae anchor themselves to the muscosa of the duodenum and jejunum of the host from which they obtain oxygen and food. The larvae reach the arterial circulation within 7-21 days and may become lodged in body tissues. However, they are capable of further

development and encystment only in skeletal muscle. The heaviest infestation occurs in the diaphragm, deltoid muscles, and muscles of the tongue, larynx, and eyelids.

Schmid (1957, p. 228) reported that the number of parasites required to cause infection varies from 15-25 for the cat to 50-75 for man. Clinical symptoms occur in man about the 5th day after infection; however, Trichinella spiralis are capable of growing at any time during the lifetime of the host. Auerbach (1960, p. 181) indicated that clinical symptoms vary with the severity and stage of infection, and include vomiting, diarrhea, sweating, and rheumatic muscular pains. Incidence of human trichinosis is highest in areas where pigs are fed uncooked garbage.

Harrell (1951, p. 421) wrote that each American consumes 3 servings of trichinae-infected pork each year. He stressed that no drug has been found effective against the larvae. Attempts to calcify the cysts by administration of calcium, parathyroid hormone, or vitamin D have accomplished little.

Personal communication with Murtishaw (1964) of MID explained that the requirement of cooking pork to 137°F is based on the work of Ransom and Schwartz (1919). However, "this early work has been repeatedly substantiated by MID and others."

Ransom and Schwartz (1919) found that Trichinella spiralis is killed when exposed to a temperature of 55°C. They suggested that death was caused by irreversible coagulation in the protoplasm. Trichinella spiralis exposed to temperatures slightly below 55°C for short periods of time may recover from this exposure. Recovery or death is dependent on the extent of protoplasm coagulation. If coagulation has proceeded beyond the stage from which

a return to normal may occur, recovery is impossible. Since MID has selected 137°F (58.3°C) as the temperature to which all pork and pork products must be heated, a certain margin of safety is provided for all items processed in plants under Federal inspection.

Data of Otto and Abrams (1939) supported the work of Ransom and Schwartz (1919) indicating that 55°C is the minimal temperature that destroys practically all larvae. However, the former workers found that a few larvae tolerated 55°C for 1 to 5 min. Otto and Abrams (1939) explained that any discrepancies between data from the 2 laboratories were probably the result of differences in heating method. In the Ransom and Schwartz (1919) work, larvae were gradually heated and cooled, whereas in the experiments of Otto and Abrams (1939) the larvae were suddenly exposed to the indicated temperatures and quickly cooled. Otto and Abrams (1939) stated, "It is hardly conceiveable that the larvae could ever be raised slowly to any temperature approaching 60°C and survive." They affirmed the Federal requirement of 137°F (58.3°C) for heat processing of pork to afford an adequate margin of safety.

Wright (1957, p. 444) reviewed the present U. S. position concerning refrigeration of pork and pork products. He reported that pork cuts not over 6 in. thick, must be held 20 days at 5°F, 10 days at -10°F or 6 days at -20°F for destruction of Trichinella spiralis. For products in layers or containers more than 6 in. thick, but less than 27 in. thick, holding times required are 30, 20, and 12 days at 5, -10, and -20°F, respectively.

Desrosier and Rosenstock (1960, p. 270) discussed the effects of irradiation on Trichinella spiralis. They stated that 15,000 rads sterilized the female parasite, whereas 25,000 rads were required to destroy the

ability of the larvae to infect animals. According to them, control of infectivity seemed possible at 50,000 rads. Perhaps these authors were thinking of 50,000 rads as a more or less "universal" control that may include garbage, and the secondary host (such as animal muscle), and man. Gibbs et al. (1961) reported that 20,000 to 30,000 rads is considered satisfactory for control of the parasite in meat. They stated that a dosage of 20,000 to 30,000 rads of cobalt-60 was effective in completely inhibiting maturation of Trichinella spiralis, and was below the level of radiation that produced deleterious changes in meat.

Palatability Factors

Recently much research has been devoted to factors affecting pork quality. Perhaps attempts to produce a meat-type hog with optimum palatability stimulated studies on relationships between palatability and weight, age, sex, and finish of the animal; and color, chemical, physical, and histological characteristics of the muscle. Also, the effect of cooking procedures on the palatability and acceptability of pork has been studied.

Juiciness. The sensation of juiciness in cooked meat has been attributed to 2 effects. The first is the impression of wetness during the first chews caused by a rapid release of meat fluids, whereas the second is a sustained juiciness resulting from a slow release of serum and the stimulating effect of fat on the flow of saliva (Weir, 1960a, p. 216). Also, she stated that probably the most important factor affecting juiciness of cooked meat is the cooking procedure. Generally, procedures that result in the greatest retention of fluids and fat yield the juiciest meat.

Weir et al. (1962) found that increasing the end point temperature (from 185 to 200°F) and the time of cooking (time to reach 200°F + 7 min and time to reach 200°F + 14 min) resulted in lower juiciness scores for braised 1-in. pork chops, whereas pork loin roasts cooked to an internal temperature of 170°F received higher juiciness scores than roasts cooked to 185°F (Weir et al., 1963). Webb et al. (1961) reported significantly ($P=0.05$) higher juiciness scores for roasts cooked to 65.6°C than those cooked to 73.6 and 85°C, but there were no significant differences between roasts cooked to 65.6°C and maintained at that temperature 1 hr and those cooked to 65.6°C.

Weir (1960b) reported that rate of cooking affected juiciness of pork loin roasts. When the internal temperature rose 2 1/4 to 2 3/4°F per min, the roasts tended to be juicier than those cooked more rapidly.

Sherman (1961) heated ground pork mixed with solutions of alkaline phosphate or sodium chloride from 25 to 100°C and found that the quantity of fluid retained by the meat decreased with increased temperature. With solutions up to 2% concentration or less, fluid retention fell initially then rose to a maximum at about 50°C. With solutions of 2 to 4%, all added fluid was absorbed prior to heating, and the point at which fluid release began depended on the additive (above 40°C for sodium chloride and 65 to 75°C for phosphates). According to regulations of USDA (1960, p. 106), pork must be heated to at least 137°F (58.3°C). The work of Sherman (1961) implies that considerable juice is lost in pork in the presence of sodium chloride before the required temperature of 137°F is attained. It further suggests that fluid is more firmly bound by pork muscle at elevated temperatures in

the presence of phosphates than in the presence of sodium chloride. Generally, with increased temperatures fluid losses increase. With less fluid retention, the meat is drier and less juicy.

Several views have been presented by workers who studied the effect of marbling on the juiciness of meat. Kauffman et al. (1964) showed that as intramuscular fat increased, juiciness increased ($r=0.70^{**}$). They postulated that intramuscular fat serves as a lubricant between muscle fibers, and thus improves juiciness.

Gaddis et al. (1950) reported that the percentage of press fluid in beef cuts tended to become lower with increased fat content and small decreases in moisture per unit of protein tended to occur with increased fat. They suggested that the potential amount of fluid would be about the same in meat cooked to the same degree of doneness regardless of the amount of fat. Intramuscular fat might hold back some of the press fluid.

In one study, Batcher and Dawson (1960) found that the greater the marbling score, the juicier the cooked meat. Correlation coefficients for marbling score and juiciness of cooked LD and rectus femoris were significant at the 1% level, and at the 5% level for the biceps femoris. However, in a later study Batcher et al. (1962) reported that marbling was related to juiciness in only a few cases. Murphy and Carlin (1961) reported that marbling scores had a highly significant positive effect on juiciness of braised pork chops, but juiciness of the chops was not significantly affected by backfat.

Tenderness. Weir (1960a, p. 218) described tenderness in meat as consisting of a minimum of 3 components: (1) the ease with which the teeth sink into meat when chewing begins, (2) the ease with which meat breaks into

fragments (friability or mealiness), and (3) the amount of residue remaining after chewing. She said that friability may reflect muscle fiber resistance to breakage perpendicular to its axis, whereas the amount of residue indicates the amount of connective tissue. Cover et al. (1962) published tenderness scores for beef based on these components.

Generally, it is believed that tenderness of cooked meat decreases as the protoplasmic proteins coagulate and increases with partial hydrolysis of collagen and softening of connective tissue. Therefore, pork loin, which usually contains a large proportion of muscle fibers to connective tissue, would be expected to become less tender as degree of doneness is increased. Webb et al. (1961) published data for pork loin roasted at 176.6°C to 65.6, 73.9, and 85°C that supported this idea, with the most pronounced reduction in tenderness occurring between 65.6 and 73.9°C. They suggested that some change in proteins, which decreased tenderness, occurred between these temperatures. Weir et al. (1963) found that degree of doneness (170 vs 185°F) had no significant effect on tenderness scores.

Visser et al. (1960) reported that tenderness scores for the loin section of the LD muscle from beef roasted in the oven at 300°F decreased significantly between end point temperatures of 55 and 70 or 85°C, whereas those for the rib section decreased significantly only between 55 and 85°C. When either section of this muscle was cooked in deep fat at 100 or 110°C (rate of cooking was more rapid than at an oven temperature of 300°F), there were no significant differences in tenderness of either section of the LD that were attributable to degree of doneness.

Rust (1963) reported that short loin beef steaks broiled to 70°C received significantly (P=0.05) higher initial tenderness scores than steaks broiled to 80 and 90°C; also, initial tenderness scores suggested that steaks broiled to 60 were more tender than those cooked to 80 or 90°C.

Pork loin roasted at 350°F with the internal temperature rising from 110 to 160°F at a rate of 2 1/4 to 2 3/4°F per min was more tender than loin that cooked more rapidly (Weir, 1960b). Tuomy and Lechnir (1964) heated strips of pork LD muscle (8 x 1 1/4 in.) in vials, placed in a wire basket in a water bath, to internal temperatures of 140, 150, 160, 180, 190, 200, and 210°F. As soon as the specified internal temperature was reached, the vials containing the meat were transferred to a bath of circulating water maintained at the run temperature. Tubes were removed after 1, 2, 3, 4, 5, 6, and 7 hr of cooking and placed in 32°F water. At 140°F there was little change in tenderness with time. At 150°F and above an appreciable tenderization occurred with time. After 4 hours cooking at 210°F, the pork fell apart so badly that it could not be sliced sufficiently well for evaluation, and at 200°F the meat fell apart so badly after 5 hr that panel evaluations would have been questionable. Falling apart was not brought about by fiber disintegration, but was caused by disintegration of the material holding the fibers together. The same authors (1963) pointed out that pork differed from beef because beef did not fall apart until cooked 8 hr at 210°F. Generally, beef became slightly more tender than pork with high-temperature cooking without falling apart.

Differences in tenderness within the LD muscle of pork have been studied. Urbain et al. (1962) found that shear cores from the lateral position were more tender than medial cores. Conversely, Murphy and Carlin (1961) reported

medial shear cores more tender than lateral cores. Weir (1953) compared several positions within pork loin among themselves, and found the LD less tender in the center than at either end. However, when the total data were analyzed, variation in tenderness attributable to position was not statistically significant.

Baird (1960) reported that posterior pork loin roasts had lower shear strengths than anterior and center roasts, which were nearly the same. However, in organoleptic evaluations, the anterior was always more tender than the posterior, which in turn was more tender than the central portion.

Harrison et al. (1956) published data showing no significant differences in tenderness of the LD from pork loin roasts held in frozen storage from 0 to 48 weeks. They stated that since storage periods were assigned to roasts from the anterior to the posterior position, no significant differences in both tenderness scores and shear values attributable to storage may indicate no significant differences from the anterior to the posterior end of the LD.

Marbling may affect tenderness as well as juiciness of pork. Kauffman et al. (1964) pointed out that when juiciness is enhanced, tenderness may be improved directly or rated higher mainly because the meat seems juicy. Batcher and Dawson (1960) and Batcher et al. (1962) reported conflicting data for the relationship of marbling to tenderness as well as to juiciness. Murphy and Carlin (1961) found that marbling had a highly significant positive effect on tenderness. They also reported that the amount of marbling within the lean was a better indication of tenderness than backfat thickness of the carcasses.

Flavor. Crocker (1948) stated that pork has an "earthy-potatoey-type flavor" with a sulfury character suggestive of chicken, and Weir (1960a, p. 219) stated that the nature and intensity of meat flavor may be partially dependent upon the type, temperature, and length of cooking. Webb et al. (1961) reported increased flavor scores with increased internal temperature (65.6, 65.6 plus 1 hr, 73.9, and 85°C) in pork loin roasts. Flavor scores were significantly ($P=0.05$) higher at 85°C than at the other temperatures, among which no significant differences were noted. They explained that cooked meat flavor is a function of the various tissue components that are combined and concentrated as time and temperature of cooking are increased. Also, they suggested that the taste panel may have been conditioned to prefer the flavor of pork cooked to 85°C. Weir et al. (1963) stated that flavor of pork loin was not significantly different when the meat was cooked to 170 or 185°F. Kauffman et al. (1964) discussed the effect of marbling on flavor in relation to its effect on juiciness. They reported that correlation coefficients of LD intramuscular fat and flavor scores were highly significant ($r=0.38^{**}$), whereas Murphy and Carlin (1961) reported that degree of marbling did not significantly affect the flavor of braised pork chops.

Weir (1960b) found that when pork loin roasts increased in internal temperature at a rate of 2 1/4°F per min the flavor was the same as for those cooked more slowly.

Color. Several factors affect the color of cooked meat or poultry. Weir (1960a, p. 213) pointed out that changes in meat pigment during cooking are determined by the type, temperature, and duration of cooking. Pigment change occurs gradually from red or pink to a lighter hue, and finally to

gray or brown. She explained that color changes are roughly related to temperatures. Internal appearance of meat tends to be as follows: below 60°C (rare), little or no color change on the interior, to 70°C (medium), decreasing pinkness, and at 75°C (well done), complete loss of pinkness.

Meyer (1960, p. 209-10) explained why the surface of uncured meat sometimes becomes red during cooking instead of the expected brown or gray color. Carbon monoxide or nitric oxide, if present in the oven atmosphere, may combine with hemoglobin or myoglobin and give a reddish color. Voegeli and Silliker (1960) gave additional reasons why thoroughly cooked fresh meat may exhibit a pink or red appearance. If meat is cooked in water that contains nitrites, or with vegetables containing nitrites such as celery, radishes, and turnips, a pink "cured meat" appearance may develop. With poultry, temperature of the flame or heat, age of the bird, and amount of fat in the skin affect the size of the area of the meat that turns pink and how extensive the pinkness becomes. Usually the thinner skin of young birds is more easily permeated and the flesh becomes pink. However, quality is not affected by the pink color.

Cover (1943) studied the effects of very slow rates of heat penetration on tenderness of beef rib, arm bone, and bottom round roasts. Cuts were cooked rare and well-done at oven temperatures of 80°C and 125°C. When the rate of heat penetration was slow enough to require 30 hr or more for the meat to lose its pink color, the roasts were consistently tender. However, when less time was used, roasts were not always tender. She reported that at oven temperatures of 80°C bottom round roasts were pink at 58 or 59°C, whereas roasts cooked in an oven of 125°C were pink (rare) at 63°C. Usually

the slower the rate of heat penetration the more well done the meat appears at a specific temperature.

Visser et al. (1960) reported that the internal appearances of beef roasts cooked in deep fat to varying internal temperatures were different from the general conception of rare, medium, and well-done meat cooked in the oven. When roasts were cooked at 110°C to internal temperatures of 45, 65, and 85°C no samples were representative of rare or medium-done meat. The surfaces were grey-brown and not the rich brown associated with oven-roasted meat. They found the center of roasts cooked to 45°C was a bright pink, and exuded red juices; however, the pinkness gradually faded to a grey-brown around the edge. Roasts cooked to 65°C were a light pink that faded to grey-brown approximately half way through the roast and roasts cooked to 85°C had uniform grey-brown interiors.

Goertz et al. (1960) reported that turkey halves roasted to 85°C in the pectoralis major and 90°C in the thigh were considered done when judged by tasting (flavor and tenderness scores); however, judging by appearance of the juice that exuded during carving, these half birds seemed slightly underdone.

Measurement and Specification of Color in Food

Color has a significant effect on the acceptability of food, and recently its measurement and control in food have received considerable attention. Francis (1963) pointed out 2 reasons for this: (1) a desire and awareness for better quality control of processes and raw material and (2) the development of adequate instruments for measurement, which have placed color control on a practical basis.

In discussing color in relation to food preference, Schutz (1954, p. 17) stated that with food it appears colors come to be identified with certain qualities and become indicators of good or bad, according to the product and its intended use. Also, he expressed the viewpoint that there does not seem to be much tendency for people to prefer foods on the basis of color alone, e.g., to prefer red foods in general to yellow foods. They learn to associate colors with various kinds of experiences with food such as taste, odor, or the total complex of stimuli associated with eating, and ultimately with the resulting satisfaction or lack thereof. On the other hand, in the discussion of Schutz's paper (1954, p. 22), M. L. Anson and S. W. Hanson gave examples that indicated color can influence what a person thinks he is tasting, and where preference was determined by color rather than flavor. A red-colored, banana-flavored jelly was identified incorrectly as raspberry flavored, whereas a more yellow chicken base tasted more like chicken than a lighter one.

General principles. "The measurement and specification of color is 'color science', combining segments of physics, chemistry, physiology, and psychology for its complete understanding" (Brice, 1954, p. 4). Kramer and Twigg (1962, p. 19) described color as a characteristic of light measurable in terms of intensity (radiant energy) and wave length, whereas Funk and Wagnalls (1946, p. 529) defined color as that quality of an object by which it emits, reflects, or transmits certain rays of light and absorbs others. Judd (1941, p. 1) referred to color as that aspect of the appearance of light that depends on spectral composition of radiant energy reaching the retina and its distribution. Brice (1954, p. 5) gave as one of the general

definitions of color: "Color is the general name for all sensations arising from the activity of the retina of the human eye and its attached nervous mechanism when light strikes the retina; light being radiant energy approximately 0.4 to 0.8 μ in wave length." He pointed out that according to this definition, color is in the mind and is not a property of an object. His explanation was that the color perceived when the eye views an illuminated object depends on: (1) the spectral composition of the light source, (2) the chemical and physical character of the object or colorant, and (3) the spectral sensitivity characteristics of the eye viewing the object. If any one of these factors is changed, the color perceived will change.

Brice (1954, p. 5) stated that to talk intelligently about the color of an illuminated object, there must be agreement on a standard light source and a standard observer. Then, color measurement and specification may be achieved by measuring light-reflecting or light-transmitting properties of an object, followed by appropriate calculations. Standard light sources and a standard observer have been adopted by International Commission on Illumination, officially abbreviated as C. I. E. (Commission Internationale de l' Eclairage, Judd and Wyszecki, 1963, p. 108). Kramer and Twigg (1962, p. 21) stated that there are 3 standard illuminants designated by C. I. E.: (1) Illuminant A--incandescent lamp 2854°K), (2) Illuminant B--noon sunlight (5000°K), and (3) Illuminant C--cloudy daylight, or north light (6800°K).

Brice (1954, p. 6, 13) explained that the standard observer is a hypothetical or average eye, determined experimentally on a number of observers who were considered normal. Its characteristics are embodied in a luminosity curve of the relative distribution of radiant energy in the visible spectrum for C. I. E. Illuminants A and C. Relative sensitivity is plotted

against wave length. The same author pointed out that most people are fairly close in their spectral sensitivity characteristics to the standard observer. Only about 5% of observers will have large deviations from the curve of the standard observer. A given colorant might bring about slightly different hue sensations among normal observers, but this difference is relatively unimportant, since usually color judgments involve comparisons.

Three attributes of color are hue, saturation, and lightness. Hue is associated with the sensation of redness, yellowness, blueness, or other colors. Saturation refers to strength of hue or freedom from mixture with white, whereas lightness indicates the brightness aspect and usually depends on the relative luminous flux transmitted or reflected by the colorant. Under ideal conditions the eye can distinguish between approximately 7 million reflected colors that differ perceptibly in combinations of hue, saturation, and lightness (Brice, 1954, p. 5).

As explained by Brice (1954, p. 5-6) color measurement is based on the experimental fact that most colors can be matched by combining 3 primary lights: red, green, and blue. Relative amounts of the 3 selected primaries required to match a specific color are the tristimulus values of color referred to by C. I. E. as X, Y, and Z. However, he pointed out that C. I. E. primaries are imaginary, because real primaries are not found that can be combined to match the highly saturated hues of the spectrum.

Instruments used. Mackinney and Little (1962, p. 195-6) classified the types of instruments available for color measurement as: (1) tristimulus photoelectric colorimeters, (2) comparators, (3) spectrophotometers, (4) visual colorimeters, both additive and subtractive, and (5) others (mainly for measurement of color in specific products). The Gardner Color-Difference

Meter is an example of a tristimulus photoelectric colorimeter. Mackinney and Little (1962, p. 203) said that such instruments must make 3 measurements to specify color. In a manual from the Gardner Laboratory (Anon. 1960, p.PH 260-Z2) it is explained that triplicate measurements are made depending upon the construction of the particular model used for measurement; e.g., either a lightness (L) or reflectance (Rd) measurement and 2 additional measurements, one for each chromaticity parameter, "a" and "b". The (Rd) scale ranges from 0 for a completely absorbing sample (black) to 100 for a completely diffusing sample (white). Rd represents 100 times the amount of light reflected by magnesium oxide (a perfectly diffusing substance) when light falls on the sample at an angle of 45° and the measuring device records the light diffused perpendicularly from the sample at 0°.

Chromaticity measurements "a" and "b" are defined in terms of tristimulus values X, Y, and Z. Redness is measured by an "a+" value and greenness by "a-", whereas "b+" indicates yellowness and "b-", blueness (Anon. Gardner Laboratory Manual, 1960, p.PH 260-Z2). According to Mackinney and Little (1962, p. 204), each of the 3 measurements (RD, "a", and "b") is made independently by 3 motor-driven devices. In another Gardner bulletin (CG-6560, 1963) it was stated that the Gardner Color-Difference Meters may be used to measure differences on solids, liquids, powders, films, and fabrics. Measurements are made against calibrated standards for each circuit, and precision is comparable to the smallest perceptible color-difference discernible by the trained eye of a human color matcher.

Mackinney and Little (1962, p. 195-211) described various color measuring instruments, and reviewed their advantages and disadvantages. Mackinney and Chichester (1954, p. 341) reported that the American Standards Association recognizes the spectrophotometer as the basic instrument in the fundamental standardization of color. However, according to Chichester (1954, p. 84), the ultimate standard is not the spectrophotometer, but rather the human eye. In any comparison of methods, the object is primarily to establish a color match that is acceptable to the eye, or to determine whether a color falls between several standards embodying attributes deemed desirable or undesirable. Wright (1957) expressed the same idea when he pointed out that whatever method is used to measure luminance and chromaticity co-ordinates, including the photoelectric spectrophotometer, none is capable to specifying color as accurately as the eye in discriminating between 2 colors of nominally the same specifications, when compared side by side in a good light.

Little et al. (1958) applied statistical methods to data obtained with a series of colored papers on numerous instruments, including 5 spectrophotometers and 3 tristimulus photoelectric colorimeters, and obtained highly significant linear relations between all instruments studied. Regression equations were calculated for each attribute of color for each instrument against an arbitrarily chosen reference spectrophotometer. In the same way, results from a series of vegetable purees whose reflectance characteristics were measured on 3 different makes of colorimeter were placed on a comparable basis, and agreement was obtained within the standard deviation.

PROCEDURE

Meat Used

Forty-eight Poland China, Duroc, and crossbred Poland China-Duroc pigs were raised by the Department of Animal Husbandry, and divided at random into 6 lots so that breed and sex were equalized. Each lot was fed a different ration from weaning (approximately 8 weeks of age) to slaughter weight (about 210 lb.). The feed was pelleted into 3/16-in. pellets, and fed free choice with water available at all times. Meat for this study was from 12 left loins of animals on 2 of the rations as given in Table 1.

Table 1. Animals and rations.

Lot	Animal numbers	Ration		
1	120-127	Control[a]		
		Ground sorghum grain (milo)	790	lbs
		Soybean oil meal	95	"
		Meat scraps	50	"
		Alfalfa meal	50	"
		"Aurofac"	5	"
		Iodized salt	5	"
		Vitamin A	400,000	I.U.
		Vitamin B_{12}	5,000	Ugs.
		B-complex vitamin (Merck 58-A)	1/2	lb
2	128-131	Control ration plus 0.2% zinc fed as $ZnSO_4 \cdot 7H_2O$		

[a]Adequate for growing swine. Contains 40.18 mg Fe and 6.79 mg Cu per lb of ration.

[b]Commercial aureomycin and vitamin B_{12}.

The pigs were held off feed about 18 hr prior to slaughter by normal procedures in the Kansas State University meat laboratory. Carcasses were dressed and chilled 24 to 48 hr before cutting. Left loins were handled as follows:

The LD was left on the vertebrae and ribs, the psoas major removed, and the fat covering trimmed to 0.5 in. The loin was separated into 3 sections or roasts designated as:

A-anterior	posterior end of 4th rib to posterior end of tenth rib.
B-middle	posterior of 10th rib to posterior of 1st lumbar vertebra.
C-posterior	posterior of 1st lumbar vertebra to anterior end of hip bone.

Each roast was wrapped in 0.0015 gauge aluminum foil, frozen at -20°F in a blast freezer, and stored at 0 to -10°F until used, approximately 2 to 4 months.

Experimental Design and Analysis of Data

A 3 x 3 Latin square, Table 2, with 4 squares or replications was used to cook the roasts. At each cooking period, sections A, B, and C from one animal were roasted to the internal temperature specified. Data for each measurement made to evaluate the cooked meat were subjected to the following analysis of variance:

Source of Variation	D/F
Squares (Replications)	3
Sections (A, B, C)	2
Internal temperatures	2
Pooled animals	8
Remainder	20
Total	35

Table 2. Design for cooking the loin roasts.

Cooking period	Square	Animal number	Treatment[a] and section[b] T_1	T_2	T_3
1	I	121	C	B	A
2		127	B	A	C
3		129	A	C	B
4	II	122	A	B	C
5		131	B	C	A
6		125	C	A	B
7	III	130	C	B	A
8		123	B	A	C
9		126	A	C	B
10	IV	128	B	A	C
11		124	A	C	B
12		120	C	B	A

[a]Treatments

T_1 -65.0°C (149°F)

T_2 -75.0°C (167°F)

T_3 -85.0°C (185°F)

[b]Section of loin

A--anterior

B--middle

C--posterior

When appropriate, least significant differences (LSD, P=0.05) were calculated. Correlation coefficients were determined for all factors within each end point on a 1410 computer and paired variates selected. Shear values for cores from medial and lateral positions in the LD were analyzed by Student's t-test.

Roasting, Sampling, and Evaluation

Prior to cooking, the wrapped meat was defrosted 48 hours in a refrigerator maintained within the range of 32 to 45°F.

Roasting. Roasts were placed on racks in individual shallow pans (12 x 7.5), and right-angle thermometers were inserted with the bulb in the center of the LD muscle. The 3 roasts to be cooked in one period were placed in the same rotary hearth gas oven (350°F) and roasted to the predetermined end point. Percentage total, volatile, and dripping cooking losses were calculated from the weight of the defrosted roast and the weight immediately after removal from the oven.

Rate of heat penetration. The time required (to the nearest 1/2 min) for each 5° rise in internal temperature was recorded until the temperature reached 55°C, and thereafter the time necessary for each 3°C rise was noted. Initial temperature of roasts ranged from -2 to 4°C. Also, the maximum internal temperature obtained by each roast after removal from the oven was recorded.

Sampling. After roasting, the LD was stripped from the bone, all exterior fat and brown surface removed, and the muscle cut into 2 pieces on a line approximately 3 in. from the anterior end. Sampling of the (LD) is illustrated in Fig. 1.

Organoleptic evaluation. Palatability samples were prepared for a 10-member panel by removing 1/2-in. cores from the anterior of the LD and cutting the cores into pieces 1/2-in. long (Figs. 1 and 2). Each panelist selected samples at random to score for juiciness, flavor, tenderness (initial impression and tenderness based on chews), and over-all acceptability. Scores within a range of 7 to 1 were recorded for each factor on Form I (Appendix).

Warner-Bratzler shear values. Warner-Bratzler shear values (25 lb dynamometer) were measured on 2 cores (1/2-in. diameter) from lateral and medial positions in each LD muscle (Fig. 1 and 2). Three shears were made on each core.

pH. Five g of cooked, ground meat were blended with 50 ml distilled water for 2 min in a Waring blendor. The homogenate sample was poured into a beaker, and pH determined using the standard scale on a Beckman pH meter (Model 76). Three measurements were made with the instrument standardized against a commercially prepared buffer, pH 6.86.

Volume of exuded fluid and press fluid. Fluid exuding from the roasts during the first 45 min after removal from the oven was poured into centrifuge tubes graduated in 0.1 ml, and the volume of total fluid, serum, and fat recorded. Duplicate 25 g samples of ground, cooked meat were pressed in a Carver Laboratory Press following a standardized 15 min time-pressure schedule with a maximum pressure of 4,000 psig. The volume of the press fluid was measured in the same manner as described for the exuded fluid.

Total moisture. The percentage moisture in the cooked LD was determined with the C. W. Brabender semi-automatic moisture tester. Duplicate 10 g samples of ground meat were weighed in calibrated dishes and subjected to a temperature of 121°F for 60 min (Fig. 4).

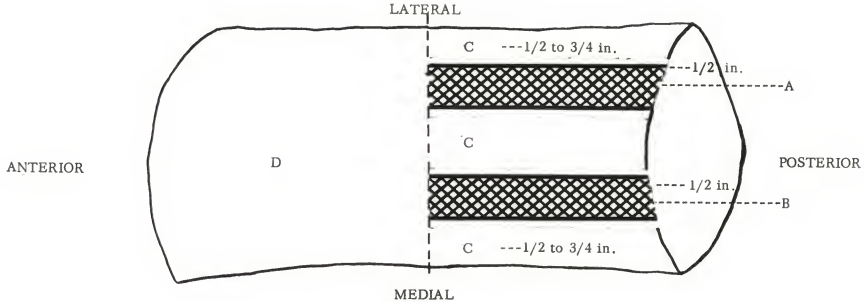
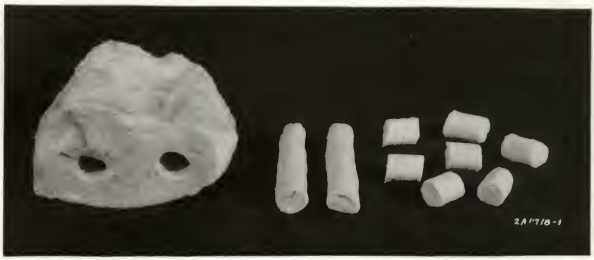


Fig. 1. Sampling the Longissimus Dorsi Muscle

A. Lateral shear core and water holding capacity.
B. Medial shear core and water holding capacity.
C. Press fluid, pH, total moisture, and color.
D. Palatability samples cut from cores 1/2-in. in diameter and 1/2-in. long.



Left Middle Right

Fig. 2. Section B with medial and lateral shear cores removed, shear cores, and palatability samples.

Left
Middle (B) section of cooked LD muscle with medial (left) and lateral (right) shear cores removed.

Middle
Left
Medial shear core

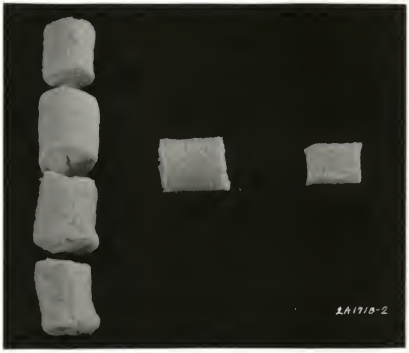
Right
Lateral shear core

Right
One-half-in. shear cores cut into 1/2-in. pieces for palatability panel.

Water holding capacity (WHC). WHC of the cooked LD was measured as described by Miller and Harrison (In Press) except that the filter paper was dried for 2 hr at 70°C and planimeter tracings were taken within ± 0.03 sq cm to determine the areas of the pressed meat and expressed liquid. Three values for WHC of each muscle were obtained from samples taken from medial and lateral 1/2-in. cores (Figs. 1 and 3). Two samples came from the medial and one from the lateral core or vice versa. The core from which 2 samples were taken was determined at random.

Color differences. An attempt was made to study the effect of end point temperature on the color of the fluid that exuded from the roasts during the first 45 min after removal from the oven and on the color of the LD muscle. Both an objective method (Gardner Color-Difference Meter values) and a subjective method (panel scores, Form II - Appendix) were used to measure differences among samples of the fluid, whereas the objective method only was used to study muscle tissue (Fig. 5-6).

Samples of the fluid that exuded from the roasts on standing 45 min were poured into centrifuge tubes; the tubes were capped with aluminum foil and placed in a refrigerator over night. The fat layer on each sample was removed with a small laboratory spatula, the tubes placed in a water bath (75 - 80°C) for 3-5 min, and 10 ml of the fluid from each tube poured into a Gardner Color-Difference Meter Glass Cell (2 1/2 in. diam) and refrigerated approximately 20 min to convert the fluid from a sol to a gel state (Fig. 5). Fluid from 9 roasts did not total 10 ml. In such cases, the total amount that exuded was used, 2.4 to 8.5 ml. Duplicate readings were made on the gel for Rd (reflectance), a- (greenness, interpreted as



Left Middle Right

Fig. 3. Shear core after shearing, portion of core for WHC sample, and WHC sample.

Left
Shear core after shearing from which WHC sample was obtained.

Middle
Portion of core from which WHC sample was taken.

Right
WHC sample (300 mg).

Left
Before drying

Right
After drying at 121°F for 60 min

Fig. 4. Samples (10 g) of ground meat in calibrated dishes used for total moisture determination in a C. W. Brabender semi-automatic moisture tester.

Left

Sample (25 g) of ground meat packed in glass cell.

Right

Fluid (10 ml) that exuded from pork loin roasts.

Fig. 5. Samples in glass cells for color determination on a Gardner Color-Difference Meter.

°C °C °C

65 75 85 65 75 85 65 75 85

Sec. C Sec. B Sec. A

Fig. 6. Appearance of fluid that exuded from pork loin roasts during a 45-min interval after removal from oven.

loss of pinkness), and b+ (yellowness) values on the Gardner Color-Difference Meter. The instrument was standardized using a satin finish ceramic tile, No. 3.5, standardized as:

Rd	a+	b+
57.30	5.07	11.69

After the objective measurements were completed, the color-difference meter cells were held in a water bath (75 to 80°C) just long enough to reverse the gel to a sol so it could be returned to the centrifuge tubes. The tubes were capped with foil and stored at -10°F for 1 to 3 weeks, then scored by a panel, using Form II (Appendix).

Before scoring, the tubes were thawed for 1 1/2 to 2 hr at room temperature or until the frozen samples became liquid. Fluid from 9 roasts (3 cooking periods) was scored by a 10-member panel under the Macbeth Skylight using the daylight illuminant. Four scoring periods occurred during the study.

Ground meat (25 g) was packed into a Gardner glass cell, and 2 readings were taken for each color-difference factor. After the first reading, the cell was rotated at 90° for the second reading.

RESULTS AND DISCUSSION

Evaluation of cooked roasts was based on palatability scores and values for selected subjective and objective measurements. Mean data are in Tables 3 and 4 and detailed data in Tables 6 to 15 (Appendix).

Subjective Measurements

Juiciness. Differences in juiciness attributable to end point temperature were significant at the 0.1% level, and mean scores decreased significantly (P=0.05) as the end point increased from 65-75-85°C (Table 3). Webb et al. (1961) reported significantly (P=0.05) higher juiciness scores for roasts cooked to 65.6°C than those cooked to 73.6 and 85°C, but there were no significant differences between roasts cooked to 65.6°C and those cooked to 65.6°C and maintained 1 hr.

Also, in the present study, juiciness scores varied significantly (P=0.05) among roasts from the anterior, middle, and posterior (A, B, and C, respectively) of the loin with mean scores for B being significantly (P=0.05) higher than those for sections A and C, which did not differ significantly from each other (Table 4). Baird (1960) found that anterior roasts always were rated significantly more juicy than posterior or middle roasts, whereas Batcher and Dawson (1960) reported that the anterior (rib end) portion of the LD muscle had higher mean juiciness scores than the posterior (loin end) portion.

Tenderness. Two factors operate during cooking to affect changes in tenderness of meat. Heat coagulates the muscle fibers and tends to harden and toughen the meat, whereas the heat plus moisture in the meat brings about a softening of collagenous tissue which tends to tenderize. Since pork loins usually contain a relatively large proportion of muscle fiber to collagenous tissue, lower tenderness scores might be expected with higher end points. However, differences in both initial tenderness scores and scores based on chews attributable to end point temperature

Table 3. Mean and F-values and LSD attributable to temperature for subjective and objective measurements.

Factor	End point, °C 65	75	85	F-value	LSD[a]
Palatability scores[b]					
Juiciness	6.3 *	5.8 *	5.3	24.19***	0.30
Tenderness					
Initial	6.0	6.0	6.0	0.01 ns	---
Based on chews	6.1	6.0	5.8	2.59 ns	---
Flavor	5.6 *	5.9 *	6.0	3.77 *	0.28
Over-all acceptability	5.8	5.7	5.6	0.41 ns	---
Color of exuded fluid[c]	3.6	3.4	3.1	2.35 ns	---
Objective measurements					
Cooking time					
Total, min	92.2 *	108.9 *	128.0	14.85***	13.7
Min/lb	32.4 *	38.3 *	43.2	15.31***	4.08
Max. temp, °C	70.1	76.3	85.3	---	---
Cooking losses, %					
Total	15.9 *	20.3 *	26.9	40.81***	2.56
Volatile	10.4 *	14.4 *	18.3	45.13***	1.72
Dripping	5.7 *	7.3	7.8	7.60**	1.12
Press fluid, ml/25 g					
Total	7.3	6.8	6.6	3.37 ns	---
Serum	6.0	5.4	5.2	2.40 ns	---
Fat	1.7	1.9	1.3	0.58 ns	---
Total moisture, %	62.9 *	60.7 *	59.3	37.05***	0.88

Table 3. (concluded)

Factor	End point, °C 65	75	85	F-value	LSD[a]
WHC[d]	0.71	* 0.69	* 0.63	9.18**	0.04
Volume of exuded fluid, ml	21.7	24.5	* 11.6	13.70***	5.39
pH	5.8	5.9	5.8	0.98 ns	---
Shear value, lb/1/2-in. core					
Medial	7.9	7.3	8.2	1.13 ns	---
Lateral	7.4	7.8	8.4	0.95 ns	---
Color difference					
Meat					
Rd	44.50	45.73	47.04	1.95 ns	---
a-	2.74	* 3.21	3.28	4.56 *	0.41
b+	11.15	* 11.41	* 11.69	9.51 **	0.26
Exuded fluid					
Rd	3.46	2.79	2.90	1.62 ns	---
a-	5.07	5.08	* 6.17	5.79 *	0.77
b+	5.11	3.85	4.87	0.89 ns	---

[a]LSD = least significant difference at 5% level.

[b]Range, 7 (very juicy, tender, desirable flavor or acceptable) to 1 (extremely dry, tough, undesirable flavor, or unacceptable).

[c]Scale, (5-brown, 4-red-brown, 3-beige, 2-pink beige, 1-pink).

[d]WHC, (1.0 - expressible-liquid index).

* , P=0.05
** , P=0.01
*** , P=0.001
ns , not significant

Table 4. Mean and F-values and LSD attributable to section for subjective and objective measurements.

Factor	Section[a] A		B		C	F-value	LSD[b]
Palatability scores[c]							
Juiciness	5.6	*	6.6	*	5.7	5.12 *	0.30
Tenderness							
Initial	6.2		5.9		5.9	3.12 ns	---
Based on chews	6.1		5.8		6.0	3.06 ns	---
Flavor	5.9		5.8		5.8	0.22 ns	---
Over-all acceptability	5.9		5.8	*	5.4	4.01 *	0.39
Color of exuded fluid[d]	3.9	*	3.1	*	3.0	8.29 **	0.49
Objective measurements							
Cooking time							
Total, min	148.4	*	94.4	*	89.4	44.09***	13.7
Min/lb	38.1		38.2		37.6	0.05 ns	---
Cooking losses, %							
Total	24.2	*	18.6	*	20.3	11.24***	2.56
Volatile	16.9	*	13.0	*	13.2	14.56***	1.72
Dripping	7.2	*	6.0	*	7.6	5.19 *	1.12
Press fluid, ml/25 g							
Total	6.9		7.1		6.8	0.49 ns	---
Serum	4.5		5.6		6.2	2.12 ns	---
Fat	1.6		0.9		0.9	0.65 ns	---
Total moisture, %	60.5	*	62.2	*	60.1	13.63***	0.88

Table 4. (concluded)

Factor	Section[a] A	B	C	F-value	LSD[b]
WHC[e]	0.65	0.69	0.66	2.21 ns	---
Volume of exuded fluid, ml	16.6	15.9 *	25.4	8.43 **	5.39
pH	5.8	5.8	5.8	0.63 ns	---
Shear value, lb/1/2-in. core					
Medial	6.8	8.5	7.9	2.00 ns	---
Lateral	8.1	9.1 *	6.3	9.94 **	1.33
Color difference					
Meat					
Rd	45.45	46.10	46.42	1.15 ns	---
a-	3.08	3.04	3.12	0.09 ns	---
b+	14.46	11.44	11.33	0.75 ns	---
Exuded fluid					
Rd	3.04	3.48	3.07	0.01 ns	---
a-	5.46	5.29	5.57	0.29 ns	---
b+	5.38	3.60	4.86	1.67 ns	---

[a]A = anterior, posterior end of 4th rib to posterior end of 10th rib.
B = middle, posterior of 10th rib to posterior of 1st lumbar vertebra.
C = posterior, posterior of 1st lumbar vertebra to anterior end of hip bone.

[b]LSD = least significant difference at the 5% level.

[c]Range, 7 (very juicy, tender, desirable flavor or acceptable) to 1 (extremely dry, tough, undesirable flavor, or unacceptable).

[d]Scale, (5-brown, 4-red-brown, 3-beige, 2-pink beige, 1-pink).

[e]WHC, (1.0 - expressible-liquid index).

* , P=0.05
** , P=0.01
*** , P=0.001
ns , not significant

were not significant (Table 3). Mean scores for initial impression of tenderness were identical for all 3 end points, whereas mean scores for tenderness based on chews decreased slightly with higher end points. Correlation coefficients for initial tenderness scores vs scores based on chews were very highly significant at 65 and 75°C and highly significant at 85°C (Table 5). Also, Weir et al. (1963) found no significant differences in initial or residue tenderness between pork loin roasts cooked to end points of 170 and 185°F.

Tenderness scores for the 3 sections of the loin did not vary significantly, but mean scores were slightly higher for the anterior than for the other 2 sections (Table 4). Baird (1960) reported a tendency for the anterior to be rated more tender than the posterior, which in turn was slightly more tender than the middle portion. Weir (1953) demonstrated similar results.

Flavor. The 3 end point temperatures resulted in significant differences in flavor. Mean scores increased significantly ($P=0.05$) between 65-75 and 65-85°C, but not between 75 and 85°C (Table 3). Weir et al. (1963) found no significant effect of end point temperature on flavor of roast pork. Webb et al. (1960) reported significantly higher flavor scores for roasts cooked to 85°C than for those cooked to 73.9, 65.6, or 65.6°C and maintained 1 hr, whereas differences among the latter 3 end points were not significant. They suggested that cooked meat flavor is a function of various tissue components that are combined and concentrated as time and temperature are increased.

No significant differences in mean flavor scores attributable to section were apparent (Table 4). Baird (1960) found that anterior cuts had

Table 5. Correlation coefficients for selected paired variates on the basis of end point temperature.

Paired variates	r		
	End point, °C		
D/F=10	65	75	85
Initial tenderness scores vs scores based on chews	0.85***	0.84***	0.76**
Juiciness vs over-all acceptability	0.56†	-0.14 ns	0.61*
Flavor vs over-all acceptability	0.64*	-0.65*	0.38
pH vs over-all acceptability	-0.18 ns	0.10 ns	-0.11 ns
Juiciness vs total cooking losses	-0.05 ns	0.13 ns	-0.35 ns
Total cooking losses vs total press fluid	0.09 ns	-0.22 ns	-0.15 ns
Juiciness vs total press fluid	-0.11 ns	0.76**	0.19 ns
Juiciness vs total moisture	-0.21 ns	-0.51†	-0.23 ns
WHC vs total press fluid	-0.54†	0.00 ns	-0.52†
WHC vs total moisture	0.68*	0.71**	0.51†
Volume of exuded fluid vs total cooking losses	0.50†	0.07 ns	0.12 ns
Volume of exuded fluid vs juiciness	0.10 ns	0.01 ns	-0.20 ns
Volume of exuded fluid vs total press fluid	-0.34 ns	-0.01 ns	0.45 ns
Volume of exuded fluid vs total moisture	-0.29 ns	0.03 ns	-0.41 ns
Exuded fluid vs WHC	-0.12 ns	-0.40 ns	-0.09 ns
WHC vs juiciness	0.48 ns	0.42 ns	0.84**

Table 5. (concluded)

Paired variates	r		
	End point, °C		
D/F=10	65	75	85
pH vs juiciness	-0.14 ns	-0.01 ns	0.07 ns
pH vs tenderness based on chews	-0.04 ns	-0.39 ns	0.03 ns
pH vs WHC	-0.45 ns	0.21 ns	-0.20 ns
pH vs total moisture	-0.36 ns	-0.30 ns	-0.14 ns
pH vs flavor	-0.66*	0.18 ns	-0.22 ns
Medial shear vs tenderness based on chews	-0.77**	-0.41 ns	-0.64*
Lateral shear vs tenderness based on chews	-0.74**	-0.80**	-0.50†
Color of meat vs color of fluid			
Rd	0.50†	0.26 ns	-0.10 ns
a-	0.31 ns	0.43 ns	0.44 ns
b+	0.01 ns	0.01 ns	-0.05 ns

†, = P=0.10
*, = P=0.05
**, = P=0.01
***, = P=0.001
ns, = not significant

higher flavor scores than those from the middle section, which in turn had higher scores than posterior cuts. Differences between the anterior and posterior roasts were significant.

Over-all acceptability. There were no significant differences in over-all acceptability ratings attributable to end point, but mean values decreased slightly from 65-75-85°C, whereas juiciness scores decreased significantly with each 10°C increment and flavor scores increased significantly ($P=0.05$) between 65-75 and 65-85°C, but not between 75-85°C (Table 3). Thus, it appears that, in general, the tasters tended to consider flavor and juiciness of about equal importance to the eating quality of the meat. Correlation coefficients for juiciness vs over-all acceptability for data within each end point were significant at the 10% level at 65°C and at the 5% level at 85°C, whereas for flavor vs over-all acceptability r-values were significant ($P=0.05$) at 65 and 75°C, but correlation coefficients for pH vs over-all acceptability were not significant (Table 5). Differences in over-all acceptability scores attributable to section were significant at the 5% level. Mean ratings decreased between the anterior and middle section and between the middle and posterior sections, but only the anterior rated significantly higher than the posterior (Table 4).

Color of exuded fluid. A panel of 10 observers scored the color of exuded fluid on a 5 point scale (Form II, Appendix). In preparing the score card, an attempt was made to describe the various color differences among the sample of fluid, then a numerical value was assigned to each descriptive term. The terminology used did not adequately describe the color of the fluid, and it seemed that for further work it would be

desirable to expand the scoring range to 7 points with additional terms and numerical values between brown and red-brown and between red-brown and beige, or to use new terms for brown and red-brown. Use of standardized terminology and reference plates such as those published by Maerz and Paul (1930) could be considered. For example, color plates might be used as a reference point to assist the observers in scoring. Also, training of the panel members to associate the terminology on the score card with colors of the fluid should be beneficial.

Differences in color scores for exuded fluid attributable to end point were not significant. Mean scores were inversely related to end point as lower scores (paler color) were noted with each 10°C increment (Table 3).

Subjective color differences of exuded fluid attributable to section of the loin were significant at the 1% level. Mean scores decreased (paler color) significantly ($P=0.05$) from the anterior to middle portion and from the anterior to the posterior, but the difference between the middle and posterior portions was not significant (Table 4).

Objective Measurements

Rate of heat penetration. Coagulation of protein is an endothermic reaction; thus, a lag frequently occurs in the rate at which the internal temperature of meat rises, and is evidenced by a flattened area in heat penetration curves. The average rate of heat penetration to 64°C for roasts from the 3 sections of pork loins is presented in Fig. 7. Anterior roasts (A) required considerably longer (63 min) to reach 10°C than roasts from middle (B) and posterior (C) sections, which required 34 and 30 min,

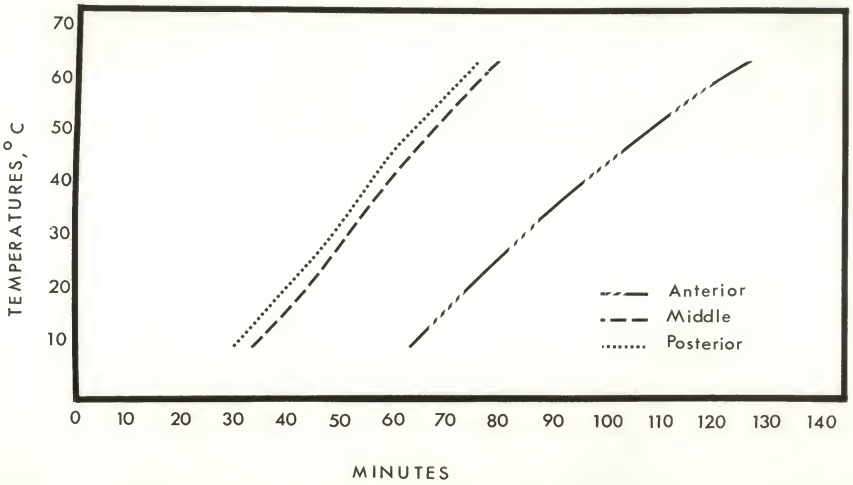


Fig. 7. Average rate of heat penetration for roasts from 3 sections of pork loins.

respectively. This seems logical since anterior (A) roasts weighed 1.3 and 1.4 lb more than B and C, respectively (Table 10, Appendix). Also, steepness of the curves is similar for B and C, whereas A rose more gradually. Perhaps more gradual heat penetration was partially responsible for the higher tenderness scores (both initial and based on chews) and lower medial shear values for A than for B and C (Table 4). Cover (1941) and Bramblett et al. (1959) reported that the tenderizing effect of low oven temperatures seemed to be the result of slow heat penetration rather than the result of low temperatures.

Heat penetration may be speeded up by inserting metal skewers into meat (Cover, 1941 and Raymond, 1963) or by cooking in water, steam, or fat instead of air (Harrison, 1943). Raymond (1963) found that copper and aluminum skewers significantly reduced cooking time of braised and roasted turkey rolls, but no significant differences in tenderness scores or shear values were noted for rolls cooked with and without skewers, whereas Cover (1941) pointed out that skewers increased the rate of heat penetration in beef roasts, but decreased tenderness. Harrison (1943) found that beef roasts cooked in water reached 70°C more rapidly than roasts cooked in fat, steam, or air, in that order.

The slower rate of heat penetration in the anterior roasts may be attributed to the fact that they were always larger than middle and posterior roasts, which were similar in size and/or to the greater amount of fat (external and seam). Thille et al. (1932) concluded that fat plays a role in the rate of heat penetration into meat, the direction of its influence depending on the location of the fat. They found that exterior fat

speeded up the rate of heat penetration, but interior fat retarded it and explained the latter on the basis of heat conductivity of the fat as it passed from the solid to the liquid state. However, Lowe (1955, p. 239) presented data from Towson in which the thickness of the external layer of fat on beef rib roasts had a definite influence on the rate of heat penetration into the interior of a roast. It took longer for heat to penetrate through a 1/2-in. layer of fat than it did for it to go through 2 in. of muscle.

Cooking time. The 3 end point temperatures resulted in very highly significant differences in cooking time, both in total min and min/lb. Mean time increased significantly (P=0.05) with each 10°C increment in end point (Table 3). Webb et al. (1961) reported that roasts cooked to 85°C required significantly longer total cooking time than roasts cooked to 73.9 or 65.5°C, but the difference was not significant between the latter end points.

Differences among sections in the average time required for the internal temperature to reach the specified end point were very highly significant, but differences in min/lb were not significantly affected by section (Table 4). Anterior (A) roasts were larger and somewhat more compact than B and C. Results of the Committee on Preparation Factors of the National Cooperative Meat Investigations (1942, p. 99) pointed out that large roasts usually require fewer min/lb than similar small roasts, whereas chunky roasts take longer to cook than flat, thin roasts. The amount and location of fat (external and seam) and the degree of ripening may also affect cooking time.

Maximum temperature. Mean values for maximum internal temperature of roasts cooked to 3 end points indicated that the amount of rise after the specified end point had been reached decreased as the end point increased (Table 3). The difference in mean maximum temperatures attained by roasts cooked to 65 and 75°C was less than the difference between mean maximum temperatures of roasts cooked to 75 and 85°C. It appears that rise in temperature after removal of the roasts from the oven did not affect the other data, because the frequency of significant differences occurred as often between 65 and 75°C as between 75 and 85°C. Visser et al. (1960) observed that beef roasts cooked to 70°C in deep fat at 110°C rose 5 to 6°C, whereas the rise in those cooked to 85°C was negligible. When Ramsbottom et al. (1945) cooked roasts from 25 beef muscles to 76.7°C in deep fat maintained at 121.1°C, the internal temperature usually rose 1 or 2 degrees after removal from the fat.

Cooking losses. Significant differences in total and volatile cooking losses that could be ascribed to end point were apparent at the 0.1% level and at the 1% level for dripping losses (Table 3). Mean values for total and volatile losses increased significantly (P=0.05) from 65-75-85°C, and dripping losses between 65-75°C and from 65-85°C. Cooking time and losses were inversely related to juiciness scores and correlation coefficients for juiciness vs total cooking losses were not significant (Table 5). Webb et al. (1961) explained lower juiciness scores with increased cooking time and internal temperature as the result of changes in muscle fibers and moisture during cooking. Differences in cooking losses attributable to section were significant (P=0.001, total and volatile; P=0.05, dripping; Table 4). Mean values for total and volatile losses were significantly

($P=0.05$) greater for A than for B and C, which were not significantly different from each other; whereas mean dripping losses were largest for C, although these losses were not significantly different from those for A (Table 4). Correlation coefficients for total cooking losses vs total press fluid were not significant (Table 5).

Press fluid yield. No significant differences among end points were found in volume of press fluid (Table 3). However, mean values for total fluid and serum always decreased as end points increased from 65-85°C, but the decrease in total fluid was less between 75-85°C than between 65-75°C. Satorius and Child (1938) found that semitendinosus muscle of beef yielded less press fluid at 75 than at 58 or 67°C, with no difference in yield between the latter end points.

In the study reported here, juiciness scores decreased significantly as end point increased (Table 3). Correlation coefficients for juiciness vs total press fluid were significant only at 75°C (Table 5). Doty (1960, p. 235) wrote that "for some types of cooked meat the press fluid obtained...is a fair index of organoleptic juiciness", but also stated that press fluid determinations give some indication of the amount of free liquid present, but should not be interpreted completely on the basis of relationship to juiciness. Gaddis et al. (1950) and Satorius and Child (1938) reported that press fluid yield was not significantly related to juiciness scores.

Section differences within the loin did not significantly affect press fluid yield; however, section B averaged the most total press fluid. Baird (1960) reported similar findings.

Total moisture. Differences in total moisture attributable to both end point and section were significant at the 0.1% level. Mean values decreased significantly (P=0.05) as the end point increased from 65-85°C and mean values for B were significantly (P=0.05) greater than those for A or C (Tables 3 and 4). Rust (1963) found that per cent total moisture of broiled short loin steaks was significantly greater in steaks cooked to 60°C than in those cooked to 70, 80, or 90°C.

Sanderson and Vail (1963) reported decreased total moisture and press fluid in beef with increased temperature. However, these authors found that the mean percentage of bound water (not released by pressing, but removed by vacuum oven drying) was increased with increased temperature. They postulated that if related to the solids in the meat, the amount of bound water might be fairly constant, regardless of temperature. Data were presented to support their premise with respective amounts of bound water being 21.8, 21.4, and 20.9 g for 140, 158, and 176°F.

The juiciness score is a subjective measurement of the sensation resulting from a composite of interrelated factors, whereas the objective measurement of total moisture does not reflect these interrelationships. In the present study, correlation coefficients within end points for juiciness scores and total moisture were negative, but only the coefficient for 75°C (r=0.51†) was significant (P=0.10), and it was only moderately high (Table 5).

Water holding capacity. There were significant (P=0.01) differences in WHC among end points with mean values decreasing significantly (P=0.05) as the end point increased from 65-85°C (Table 3). The lower the WHC

value, the less liquid expressed; correlation coefficients for WHC and total press fluid were negative and significant at the 10% level for 65 and 85°C, whereas correlation coefficients for WHC and total moisture were positive and significant at the 5, 1, and 10% levels for the end points 65, 75, and 85°C. Differences in WHC were not significantly affected by section (Table 4). Mean values were the greatest for B, followed by C, which was similar to A.

Volume of exuded fluid. Differences among end points in the volume of exuded fluid were significant (P=0.001) with mean values for roasts cooked to 85°C significantly (P=0.05) less than those for roasts cooked to 65 or 75°C, and no significant difference between mean values for 65 and 75°C (Table 3). This seems logical, because total cooking losses increased significantly (P=0.05) as end point increased (Table 3). Also, mean data for juiciness scores, volume of total press fluid, percentage total moisture, and WHC follow the same pattern as that for exuded fluid and indicate that the meat contained less juice, fluid, or moisture as end point increased (Table 3).

Correlation coefficients for volume of exuded fluid and percentage total cooking losses were significant at the 10% level at 65°C, but not significant at 75 and 85°C (Table 5). Correlation coefficients for volume of exuded fluid vs juiciness, total press fluid, total moisture, and WHC were not significant. Whereas r-values for WHC vs juiciness were not significant at 65 and 75°C, but highly significant at 85°C.

Differences in volume of exuded fluid among sections of the loin were significant (P=0.01) with mean values for C significantly (P=0.05)

higher than those for A and B (Table 4). The smallest volume of fluid exuded was from section B, whereas this section had the least cooking losses and highest values for juiciness, total moisture, press fluid, and WHC. Thus, it appears that the middle section (B) of the loin had greater ability for retaining juices during cooking than the anterior (A) or posterior (C) sections.

pH. The pH of cooked meat was not affected significantly by end point or section of the loin (Tables 3 and 4). Moreover, correlation coefficients for pH vs juiciness and tenderness scores based on chews, WHC, and total moisture all were not significant (Table 5). These correlation coefficients do not indicate the same relationships among certain characteristics of cooked meat as reported for raw muscle. Kauffman et al. (1964) pointed out that Briskey (1958) implied that as pH decreased to about 5.5, the isoelectric point of major pork muscle proteins, the amounts of expressible water increased. Judge et al. (1960) and Kauffman et al. (1964) found more expressible juice as pH decreased. In this study, at 65°C the correlation coefficient for pH vs flavor ($r=-0.66^*$) was significant (Table 5). However, examination of the data for individual roasts revealed that more desirable flavor was associated with lower pH in half of the samples, whereas less desirable flavor was associated with the lower pH in the other half of the samples.

Shear values. There were no significant differences among end points in shear values for cores from either the lateral or medial position in the LD muscle (Table 3). Both medial and lateral cores mean values were highest at 85°C, whereas for medial cores they were lowest at 75, and for lateral cores lowest at 65°C.

For both medial and lateral cores 2 out of 3 correlation coefficients were significant (P=0.05 or 0.01) for shear values vs tenderness scores based on chews (Table 5). When shear values were analyzed for differences among sections there were no significant differences for medial cores, but differences among lateral cores were significant (P=0.01) with mean values for C significantly (P=0.05) lower than those for A and B (Table 4). Section B had the highest mean shear values in both lateral and medial cores. Also, Weir (1953) reported that the central portion of the LD had the highest shear values. When data were analyzed by "t" test, irrespective of end point or section, there was no difference in shear values between the medial and lateral positions of the LD.

Color differences. Differences in reflectance (Rd) attributable to end point temperature were not significant for meat and exuded fluid (Table 3). Mean Rd values for the meat increased as end point temperature increased, which indicated greater reflectance of wave lengths or increased whiteness with increased end points. Although differences among end points were not significant, their trend agrees with the concept that greater whiteness is associated with more well-done pork. Perhaps with more extensive coagulation, the protein structure becomes more compact, and thereby absorbs less wave lengths, or conversely, reflects more light. There was no linear pattern in Rd for exuded fluid. The fluid from roasts cooked to 65°C reflected the most wave lengths, whereas fluid from roasts cooked to 75°C reflected the least (Table 3). Correlation coefficients for Rd of meat vs Rd of fluid were significant at the 10% level at 65°C and not significant at 75 and 85°C (Table 5).

Differences in greenness, or loss of pink color, (a-), in meat and exuded fluid attributable to end point temperatures were significant at the 5% level. Mean values for the meat were significantly ($P=0.05$) less at 65 than at 75 or 85°C (Table 3). Thus, as end point increased, pinkness decreased. Loss of pinkness was greater between 65 and 75°C than between 75 and 85°C. Values for a- of the exuded fluid from roasts cooked to 85°C were significantly less pink than fluid from roasts cooked to 65 and 75°C, but there was no significant difference between 65 and 75°C.

Griswold (1962, p. 114-116) ascribed the color of muscle chiefly to the red tissue pigment, myoglobin, and its derivatives, and described the color changes in this pigment brought about by oxidation and cooking. Oxymyoglobin, the bright red pigment in raw meat, results from the combination of oxygen and myoglobin. As meat is cooked, and the internal temperature rises, the proportion of oxymyoglobin decreases. The pigment formed, denatured globin hemichrome, is responsible for the color of well-done meat.

No significant differences in color difference for Rd, a-, or b+ could be ascribed to section in either the meat or exuded fluid. Mean values for meat Rd increased from the anterior to the posterior sections. No such pattern was noted for Rd of the fluid, as section B reflected the most light, whereas C and A were similar.

Mean a- values were the highest for C in both the meat and fluid followed by A and B (Table 4). Correlation coefficients for a- of meat vs a- of exuded fluid were not significant; however, relationships increased with higher end points and approached significance at the 10% level at 85°C (Table 5).

Yellowness, b+ differences attributable to end point were highly significant for the meat, but not significant for exuded fluid (Table 3). Mean values of the meat increased significantly (P=0.05) as end points increased from 65-75-85°C whereas fluid from roasts cooked to 65°C had the highest mean value (the most yellow) and that from roasts cooked to 75°C the lowest mean value. Correlation coefficients for b+ of fluid vs b+ of meat were not significant (Table 5).

Yellowness mean values in both the meat and juice were the highest in section A. Yellowness of the meat was greater in B than C, whereas the fluid was more yellow in C than B (Table 4). Perhaps this suggests that pigment lost from the muscle to the juice results in less intensive yellowness in the meat but increases the value of the juice.

SUMMARY

Anterior (A), middle (B), and posterior (C) sections of 12 pork loins were roasted at 350°F to study the effects of 3 end point temperatures (65, 75, 85°C) on the palatability and certain related characteristics of the longissimus dorsi (LD), and differences that occurred from the anterior to the posterior end of the loin. A 3x3 Latin square with 4 replications was followed to cook 36 roasts.

Measurements on cooked LD included: scores for juiciness, tenderness, flavor, over-all acceptability, and color of fluid that exuded 45 min after the end point was attained; volume of press fluid and exuded fluid; water holding capacity (WHC); percentage total moisture; pH; Warner-Bratzler shear and Gardner Color-Difference values for (Rd, a-, b+) for meat and exuded fluid. Rate of heat penetration and cooking time and losses were

noted. Data for each factor was subjected to analysis of variance, and when appropriate, least significant differences (P=0.05) were calculated. Shear values for medial and lateral positions in the LD were subjected to Student's t-test.

There was no marked organoleptic preference for one end point, but 65 or 75°C resulted in significantly lower weight loss than 85°C. Section B retained more juice during roasting than A or C, which was evidenced in having the smallest volume of exuded fluid, the least cooking losses, and highest values for juiciness, total moisture, press fluid, and WHC.

Juiciness, total moisture, and WHC decreased significantly with each 10°C increment in end point. Exuded fluid was significantly (P=0.05) lower at 85 than at 75 or 65°C, whereas press fluid and pH were not affected significantly. Section B was rated significantly higher than A or C in juiciness and total moisture, whereas volume of exuded fluid was significantly greater for C than for A or B. Differences among sections were not significant for WHC, press fluid, or pH.

Tenderness was not significantly affected by end point or medial or lateral position. However, lateral shear values were significantly lower for section C than for A or B. End points of 75 and 85°C produced significantly higher flavor scores than 65°C, but the 3 sections were not significantly different. Over-all acceptability decreased slightly as end point increased and section C was significantly less acceptable than A.

Cooking time and losses (total and volatile) increased significantly with each increase in end point and drippings between 65-75 and 65-85°C.

Total cooking time was significantly greater for section A than for B or C, but differences in min/lb were not significant. Total and volatile losses were significantly greater for A than for B and C, whereas drippings were significantly greater for A and C than for B. Differences in Rd values among end points were not significant for meat or exuded fluid, but meat values were slightly higher with each 10°C increment in end point. Meat a- values (loss of pinkness) increased significantly from 65-75-85°C, whereas those for exuded fluid were significantly greater at 85 than at 65 or 75°C. Meat b^+ (yellowness) values were significantly greater with each increment in end point, but there was no significant effect on b^+ values or panel scores for exuded fluid. Section did not significantly affect color of meat or exuded fluid.

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APPENDIX

FORM 1

SCORE CARD FOR PORK LOIN ROASTS COOKED TO THREE END POINT TEMPERATURES

Name_____ CODE_____ Date _____

Sample Number	Juiciness	Flavor	Initial	Tenderness		Over-all acceptability	
				Chews No.	Score	Score	Reason and/or comments: Why did you give the score you did?
1							
2							
3							

Descriptive terms for scoring:

Juiciness	Flavor	Tenderness	Over-all acceptability
7. Very juicy	7. Very desirable	7. Very tender	7. Very acceptable
6. Juicy	6. Desirable	6. Tender	6. Acceptable
5. Moderately juicy	5. Moderately desirable	5. Moderately tender	5. Moderately acceptable
4. Slightly dry	4. Slightly desirable	4. Slightly tough	4. Slightly acceptable
3. Dry	3. Neutral	3. Tough	3. Neutral
2. Very dry	2. Slightly undesirable	2. Very tough	2. Slightly unacceptable
1. Extremely dry	1. Undesirable	1. Extremely tough	1. Unacceptable

FORM 2

SCORE CARD FOR APPEARANCE OF FLUID FROM
PORK LOIN ROASTS COOKED TO THREE END POINT TEMPERATURES

Name _____ Code _____ Date _____

Sample Number	Color score	Comments
1		
2		
3		
4		
5		
6		
7		
8		
9		

Descriptive terms for scoring:
Color: 5. brown 3. beige
4. red-brown 2. pink-beige
1. pink

Assign each sample a score representing the descriptive term that best describes the color of the fluid.

Table 6. Juiciness scores[a], total moisture, and WHC.

Section	End point, °C 65	75	85	Section	End point, °C 65	75	85	Section	End point, °C 65	75	85
	Juiciness				Total moisture, %				WHC[b]		
A	7.2	6.3	5.4	A	60.45	57.50	57.85	A	0.64	0.59	0.65
	5.8	5.8	4.9		63.33	60.90	61.45		0.67	0.66	0.64
	5.9	5.6	4.3		64.63	59.21	58.29		0.78	0.69	0.69
	6.1	5.1	5.2		59.29	64.28	59.30		0.49	0.73	0.61
Av.	6.3	5.7	5.0	Av.	61.93	60.47	59.22	Av.	0.65	0.67	0.65
B	6.2	6.4	6.6	B	62.45	60.95	58.60	B	0.74	0.59	0.57
	6.4	5.5	5.7		66.55	62.85	60.40		0.71	0.75	0.68
	6.1	6.3	5.0		66.07	62.41	61.73		0.80	0.79	0.65
	6.3	6.1	6.1		63.70	62.20	58.71		0.79	0.72	0.40
Av.	6.3	6.1	5.9	Av.	64.69	62.10	59.86	Av.	0.76	0.71	0.58
C	6.1	6.8	5.3	C	61.20	58.62	56.05	C	0.67	0.58	0.53
	6.8	4.7	4.5		62.80	61.02	60.60		0.73	0.58	0.65
	6.0	5.1	5.2		61.55	61.90	58.10		0.77	0.74	0.76
	6.4	6.3	5.2		62.85	56.46	60.55		0.73	0.60	0.67
Av.	6.3	5.8	5.1	Av.	62.10	59.50	58.83	Av.	0.73	0.63	0.62

[a]Range, 7 (very juicy) - 1 (extremely dry).

[b]WHC = (1.0 - expressible-liquid index).

Table 7. Percentage cooking losses of roasts.

Section	End point, °C 65	75	85	Section	End point, °C 65	75	85	Section	End point, °C 65	75	85
	Total				Volatile				Dripping		
A	20.22	24.97	29.77	A	11.01	17.70	21.54	A	9.06	7.13	8.13
	19.96	25.32	28.56		15.84	19.36	22.15		3.91	5.79	6.24
	16.84	23.45	32.00		12.16	14.25	18.78		4.47	8.97	12.83
	20.16	20.47	29.16		12.78	16.16	21.19		7.15	4.39	8.12
Av.	19.30	23.55	29.87	Av.	12.95	16.87	20.92	Av.	6.15	6.57	8.83
B	14.81	21.60	25.93	B	9.14	22.36	18.13	B	5.37	7.57	7.47
	13.47	19.28	26.31		6,69	13.50	18.15		5.88	5.26	8.01
	12.62	21.09	22.85		7.19	10.26	16.13		5.08	10.45	6.09
	2.31	16.45	26.05		8.65	10.63	14.52		3.08	5.48	3.71
Av.	10.80	19.61	25.35	Av.	7.92	14.19	16.73	Av.	4.79	7.19	6.32
C	18.22	23.57	27.69	C	12.26	13.34	18.97	C	6.39	9.90	8.32
	15.82	23.68	28.53		9.63	12.05	18.57		5.53	9.34	9.51
	21.41	10.93	21.71		10.14	13.31	13.16		10.89	6.52	8.37
	14.79	12.73	24.29		9.57	9.46	17.73		4.12	6.42	6.17
Av.	17.56	17.73	25.56	Av.	10.40	12.04	17.11	Av.	6.73	8.05	8.09

Table 8. Scores[a] for flavor and over-all acceptability, and total cooking time in minutes and minutes per pound.

Section	End point, °C 65	75	85	Section	End point, °C 65	75	85	Section	End point, °C 65	75	85	Section	End point, °C 65	75	85
	Flavor				Over-all acceptability				Total min				Min/lb		
A	6.6	6.1	6.2	A	6.9	6.3	6.0	A	125	134	186	A	23.33	39.41	41.42
	5.8	6.1	5.6		6.0	5.9	5.7		70	171	166		22.15	45.84	41.60
	5.8	6.3	5.7		5.8	5.8	5.2		132	158	170		31.13	40.82	42.93
	4.8	5.8	5.8		6.0	5.7	5.8		149	126	156		38.11	39.87	50.81
Av.	5.8	6.1	5.8	Av.	6.2	5.9	5.7	Av.	119	147	170	Av.	28.68	41.49	44.19
B	5.6	5.5	6.7	B	5.3	5.6	5.8	B	79	105	96	B	35.74	40.54	51.39
	6.2	5.7	6.3		6.0	5.7	6.0		77	85	113		33.92	33.74	37.79
	5.2	5.6	5.9		5.4	5.9	5.4		76	88	117		30.28	38.26	41.94
	5.4	5.6	6.1		5.7	6.0	6.2		82	88	127		35.81	33.21	45.52
Av.	5.6	5.6	6.3	Av.	5.6	5.8	5.9	Av.	79	92	113	Av.	33.94	36.43	44.16
C	5.8	7.0	5.9	C	5.7	4.2	4.9	C	94	96	98	C	37.45	36.50	43.17
	5.3	5.7	5.9		5.6	5.5	5.2		69	100	119		29.87	38.61	40.77
	5.4	5.8	5.6		5.3	5.5	5.8		79	76	90		33.62	32.07	37.66
	5.6	5.7	5.9		5.7	6.1	5.4		74	80	98		37.37	40.82	43.56
Av.	5.5	6.1	5.8	Av.	5.6	5.3	5.3	Av.	79	88	101	Av.	34.57	37.00	41.29

[a]Range, 7 (very desirable, acceptable) - 1 (undesirable, unacceptable).

Table 9. Total fluid exuded and tenderness scores[a].

Section	End point, °C 65	75	85	Section	End point, °C 65	75	85	Section	End point, °C 65	75	85
	Total fluid exuded, ml				Tenderness Initial				Tenderness Based on chews		
A	34.6	15.8	13.5	A	7.2	6.1	5.9	A	7.2	6.0	5.9
	35.0	12.5	5.5		6.4	5.9	6.0		6.1	5.9	6.0
	19.5	14.8	10.5		6.0	5.6	6.3		5.8	5.4	5.9
	8.9	19.4	9.0		6.1	6.5	6.3		6.6	6.5	6.1
Av.	24.5	15.6	9.6	Av.	6.4	6.0	6.1	Av.	6.5	6.0	6.0
B	13.8	33.5	8.6	B	4.8	5.6	7.3	B	5.0	5.6	6.1
	17.9	33.5	8.3		6.0	5.3	5.8		6.0	5.5	5.8
	11.8	15.8	3.3		5.6	5.8	5.4		5.4	5.8	5.4
	12.7	20.9	10.4		6.1	6.2	6.6		6.1	6.3	6.4
Av.	14.1	25.9	7.7	Av.	5.6	5.7	6.3	Av.	5.6	5.8	5.9
C	40.1	46.1	13.5	C	6.1	6.8	4.8	C	6.1	6.3	4.8
	18.3	38.8	22.5		6.0	6.1	5.7		5.9	6.7	5.9
	25.7	24.8	27.5		5.9	5.6	5.9		6.1	5.6	5.9
	22.1	18.2	7.1		6.0	6.5	6.1		6.8	6.5	5.3
Av.	26.6	32.0	17.7	Av.	6.0	6.3	5.6	Av.	6.2	6.3	5.5

[a]Range, 7 (very tender) - 1 (extremely tough).

Table 10. Initial weight, pH, and panel color scores[a].

Section	End point, °C 65	75	85	Section	End point, °C 65	75	85	Section	End point, °C 65	75	85
	Initial weight, g				pH				Panel color scores		
A	2043	1542	2042	A	5.74	5.88	5.58	A	4.0	3.8	4.4
	1433	1692	1810		5.65	5.77	5.68		4.1	4.1	4.2
	1924	1761	1800		5.75	5.89	5.89		4.1	3.7	2.9
	1776	1436	1392		6.13	5.71	5.79		4.6	3.6	3.3
Av.	1794	1608	1761	Av.	5.82	5.81	5.74	Av.	4.2	3.8	3.7
B	1006	1176	910	B	5.83	5.72	5.83	B	3.8	2.8	3.0
	1032	1141	1361		5.76	5.62	5.68		2.6	2.4	2.6
	1141	1043	1265		6.15	5.89	5.77		2.8	4.4	2.6
	1040	1204	1267		5.73	5.81	5.89		3.5	3.5	3.3
Av.	1055	1116	1201	Av.	5.87	5.76	5.79	Av.	3.2	3.3	3.8
C	1141	1192	1033	C	5.69	5.80	5.76	C	3.4	2.8	2.8
	1049	1178	1325		5.78	5.67	5.71		3.0	4.3	2.4
	1065	1074	1087		5.91	6.21	5.94		4.2	2.7	2.7
	899	888	1021		5.70	5.92	5.93		2.7	2.8	2.6
Av.	1039	1083	1117	Av.	5.77	5.90	5.84	Av.	3.3	3.2	2.4

[a]Range, 5 (brown) - 1 (pink).

Table 11. Press fluid yield.

Section	End point, °C 65	75	85	Section	End point, °C 65	75	85	Section	End point, °C 65	75	85
	Total, ml/25 g				Serum, ml/25 g				Fat, ml/25 g		
A	7.1	6.5	6.0	A	5.6	2.0	4.1	A	2.5	4.5	1.8
	7.3	6.3	6.1		6.5	5.3	5.5		0.8	1.1	0.6
	7.0	6.5	7.1		6.5	5.5	5.5		0.5	1.1	1.6
	8.9	6.6	7.0		4.0	6.3	4.5		2.0	0.4	1.6
Av.	7.6	6.5	6.6	Av.	5.7	4.8	4.9	Av.	1.5	1.8	1.4
B	8.8	6.7	6.8	B	6.0	5.8	5.0	B	8.5	0.9	1.8
	8.3	6.1	6.1		8.1	5.7	5.2		0.2	0.4	0.9
	6.1	7.9	6.2		4.7	7.0	5.6		1.5	0.9	0.6
	7.2	7.2	7.7		6.3	5.6	5.5		0.4	0.9	2.0
Av.	7.6	7.0	6.7	Av.	6.3	6.0	5.3	Av.	2.7	0.8	1.3
C	6.8	8.0	6.6	C	6.0	4.7	4.2	C	0.8	2.5	2.7
	6.5	5.8	6.3		5.7	5.0	5.6		0.8	0.8	0.7
	7.0	6.4	7.8		6.4	5.7	6.9		1.2	0.7	0.9
	7.1	7.8	5.9		6.2	5.6	5.2		0.9	1.4	0.8
Av.	6.9	7.0	6.7	Av.	6.1	5.3	5.5	Av.	0.9	1.4	1.3

Table 12. Maximum temperature and shear values.

Section	End point, °C 65	75	85	Section	End point, °C 65	75	85	Section	End point, °C 65	75	85
	Maximum temperature				Shear values lateral				Shear values medial		
A	72.0	78.0	---	A	6.8	8.0	6.6	A	5.8	7.4	6.6
	74.0	75.0	85.0		8.8	9.2	7.9		6.5	8.6	7.0
	70.0	75.0	85.0		11.2	10.2	9.1		8.5	7.5	6.1
	73.0	78.5	87.0		5.1	6.7	7.2		4.9	7.6	9.4
Av.	72.2	76.6	85.7	Av.	8.0	8.5	7.7	Av.	6.4	7.8	7.3
B	70.0	---	85.0	B	14.2	8.7	7.8	B	13.7	6.0	9.9
	68.0	76.0	85.0		7.4	7.6	10.3		6.3	9.3	8.8
	70.0	75.5	85.0		12.0	9.1	11.5		11.3	8.0	10.5
	69.5	75.5	85.0		9.0	7.1	4.1		8.2	6.1	4.2
Av.	69.4	75.7	85.0	Av.	10.7	8.1	8.4	Av.	9.9	7.4	8.4
C	---	77.5	85.0	C	4.2	5.8	7.6	C	4.4	7.8	11.1
	65.0	75.0	85.0		5.6	4.5	9.1		5.4	7.5	7.0
	71.0	78.5	86.0		6.3	7.1	7.0		7.7	11.2	9.8
	69.0	76.0	85.0		4.3	3.8	9.9		5.6	6.4	9.9
Av.	68.3	76.8	85.3	Av.	5.1	5.3	8.4	Av.	5.8	8.2	9.5

Table 13. Gardner color-difference measurements of ground meat.

Section	End point, °C 65	75	85	Section	End point, °C 65	75	85	Section	End point, °C 65	75	85
	Rd				a-				b+		
A	44.90	48.29	46.77	A	2.69	4.12	4.13	A	11.18	11.40	12.22
	45.45	51.08	42.41		3.56	4.98	2.90		11.35	11.46	11.76
	44.17	42.19	42.58		2.85	3.72	1.80		11.80	11.50	11.11
	44.53	45.17	47.85		2.09	1.94	2.13		11.12	11.30	11.54
Av.	44.76	46.68	44.90	Av.	2.98	3.69	2.74	Av.	11.36	11.42	11.66
B	45.16	46.37	42.93	B	2.91	3.84	2.84	B	11.68	11.81	11.49
	42.66	47.31	59.67		2.38	3.95	4.60		10.00	12.32	11.61
	46.66	40.20	45.57		4.04	1.55	3.09		11.35	11.08	12.22
	45.96	44.69	46.05		1.90	1.27	4.05		11.18	10.97	11.46
Av.	45.11	44.64	48.55	Av.	2.83	2.65	3.65	Av.	11.05	11.55	11.70
C	45.75	44.79	46.53	C	3.58	3.04	4.02	C	11.52	11.59	11.97
	51.68	45.11	51.70		4.33	3.32	4.41		11.20	11.21	12.12
	41.68	46.99	46.78		0.98	3.65	2.60		10.77	11.75	11.32
	46.80	47.52	45.68		1.52	3.17	2.82		10.64	10.58	11.40
Av.	46.47	46.10	47.67	Av.	2.60	3.30	3.46	Av.	11.03	11.28	11.70

Table 14. Gardner color-difference measurements of fluid that exuded during 45 min after taking from the oven.

Section	End point, °C 65	75	85	Section	End point, °C 65	75	85	Section	End point, °C 65	75	85
	Rd				a-				b+		
A	2.55	2.97	2.25	A	5.10	5.95	5.35	A	3.90	5.86	6.06
	2.30	3.65	2.89		5.46	3.99	7.74		4.61	8.96	4.66
	3.25	4.11	3.05		5.18	6.17	6.13		4.32	6.61	4.60
	3.85	2.88	2.76		4.57	4.60	5.23		7.62	4.89	2.45
Av.	2.99	3.40	2.74	Av.	5.08	5.18	6.11	Av.	5.11	6.58	4.44
B	2.66	1.78	4.61	B	5.68	5.58	6.84	B	4.66	0.36	0.40
	2.42	2.15	3.20		5.78	6.17	6.83		5.30	0.52	1.80
	4.71	1.85	1.70		3.12	3.72	5.35		5.28	3.30	9.85
	5.36	2.18	3.75		3.92	3.98	6.51		5.26	1.30	2.67
Av.	3.79	1.99	3.32	Av.	4.63	4.86	6.38	Av.	5.13	1.37	3.68
C	3.46	2.77	3.27	C	6.00	5.79	7.16	C	5.95	2.87	1.81
	3.65	2.33	2.50		6.55	5.50	7.76		6.35	0.90	1.94
	1.67	2.14	2.41		3.97	4.00	4.80		3.32	9.85	9.87
	5.62	4.65	2.40		5.51	5.53	4.28		4.80	3.27	9.85
Av.	3.60	2.97	2.65	Av.	5.51	5.21	6.00	Av.	5.11	4.22	5.87

Table 15. Correlation coefficients among 22 measurements for 3 end point temperatures.

	a	b	c	d	e	f	g	h	i	Line
Key	a	-.14	-.11	-.04	.06	-.27	.10	-.12	.48	1
		-.01	.76	-.20	.52	-.19	.01	-.29	-.09	2
65°C=horizontal line 1		.07	.19	-.21	.39	.11	-.20	-.57	.25	3
75°C=horizontal line 2										
85°C=horizontal line 3	b		.43	-.64	.23	.40	-.60	-.45	-.04	1
			.15	-.01	.11	-.05	-.41	.21	-.39	2
a=juiciness			.64	.53	.03	-.50	.15	-.20	.03	3
b=pH										
c=press fluid, total	c			.05	.52	.35	-.34	-.54	-.04	1
d=press fluid, serum				.22	.19	-.12	-.01	-.00	.21	2
e=press fluid, fat				.45	.35	.13	.45	-.52	.43	3
f=fluid exuded, panel										
g=fluid exuded, total	d				-.21	-.34	.27	.43	-.11	1
h=WHC					-.90	-.05	-.04	.61	-.12	2
i=tenderness, chews					-.61	-.39	.42	.20	.27	3
j=over-all acceptability										
k=cooking losses, total	e					.23	-.21	-.05	-.43	1
l=total moisture						.09	-.06	-.54	.10	2
m=tenderness, initial						.20	.02	-.68	-.11	3
n=flavor										
o=shear, lateral	f						.13	-.46	.17	1
p=shear, medial							-.44	.07	.25	2
Color difference, meat							-.22	-.19	-.37	3
q=Rd										
r=a-	g							-.12	.39	1
s=b+								-.40	.19	2
Color difference, fluid								-.09	.09	3
t=Rd										
u=a-	h								-.53	1
v=b+									-.40	2
									-.28	3
	i								---	

Table 15. (continued)

		j	k	l	m	n	o	p	q	r	Line
Key	a	.56	-.05	-.21	.46	.44	-.29	-.26	.36	-.08	1
		-.14	.13	-.51	.29	.32	-.13	-.47	-.05	.08	2
65°C=horizontal line 1		.61	-.35	-.23	.50	.80	-.41	.11	.06	-.26	3
75°C=horizontal line 2											
85°C=horizontal line 3	b	-.18	.23	-.36	-.25	-.66	-.01	.11	-.22	.24	1
		.10	-.40	-.30	-.17	.18	.24	.34	-.22	.05	2
a=juiciness		-.11	-.42	-.14	.34	-.22	-.11	.16	-.36	.56	3
b=pH											
c=press fluid, total	c	.10	.09	-.26	-.28	-.06	.12	.11	-.43	.36	1
d=press fluid, serum		-.25	-.22	-.32	.54	.24	-.18	-.35	-.40	.53	2
e=press fluid, fat		.24	-.15	-.48	.34	-.17	-.62	-.14	-.23	.33	3
f=fluid exuded, panel											
g=fluid exuded, total	d	.00	-.19	.53	.01	.60	.04	-.03	-.32	.21	1
h=WHC		-.08	-.37	.60	-.20	-.41	.08	.09	-.44	.46	2
i=tenderness, chews		.08	-.54	.33	.11	-.40	.11	-.03	-.03	.25	3
j=over-all acceptability											
k=cooking losses, total	e	-.20	-.08	-.25	-.57	-.02	.55	.67	-.06	-.04	1
l=total moisture		.02	.37	-.70	.35	.50	-.01	-.19	.22	-.26	2
m=tenderness, initial		-.05	.36	-.87	.04	.32	-.59	-.04	-.21	-.10	3
n=flavor											
o=shear, lateral	f	.22	.49	.65	.19	-.12	.07	-.01	-.39	.25	1
p=shear, medial		.33	.54	.11	.09	-.07	.25	-.16	-.28	.19	2
Color difference, meat		.46	.44	-.10	.19	-.01	-.51	-.44	-.36	.02	3
q=Rd											
r=a-	g	.40	.50	-.29	.55	.62	-.39	-.46	-.10	-.14	1
s=b+		-.80	.07	.03	.15	.26	-.45	.03	-.05	-.03	2
Color difference, fluid		-.08	-.12	-.41	-.17	-.24	-.31	.06	.18	-.16	3
t=Rd											
u=a-	h	-.54	-.52	.68	-.38	.08	.48	.55	.11	-.05	1
v=b+		.24	-.34	.71	-.44	-.35	.42	.49	-.37	.43	2
		-.29	-.07	.51	-.29	-.26	.84	.31	.14	.26	3
	i	.75	.29	-.51	.85	-.30	-.74	-.77	-.09	.40	1
		-.12	-.01	-.12	.84	.02	-.80	-.41	.05	.40	2
		.73	.20	.16	.76	.17	-.50	-.64	-.03	.12	3

j	.26	-.28	.86	.64	-.30	-.51	-.11	.00	1
	-.14	-.01	-.34	-.65	.24	-.19	.17	-.02	2
	-.17	.11	.55	.38	-.49	-.36	.20	-.15	3
k		-.52	.27	.14	-.31	-.33	-.24	-.03	1
		-.08	.04	-.42	.40	-.23	-.03	-.29	2
		-.23	.08	-.13	-.17	-.51	-.09	.05	3
l			-.30	.14	.49	.39	.03	-.24	1
			-.33	-.44	.25	.36	-.22	.38	2
			.06	-.13	.57	-.10	.17	.02	3
m				.49	-.55	-.72	-.03	.06	1
				.43	-.62	-.42	-.00	.38	2
				.46	-.34	-.32	-.30	.37	3
n					.01	-.14	-.26	-.03	1
					.03	.12	.02	-.25	2
					-.06	.02	.23	-.41	3
o						.93	-.10	-.25	1
						.17	-.16	-.20	2
						.43	.26	.08	3
p							.11	-.09	1
							.17	-.29	2
							.08	.19	3
q								-.65	1
								-.69	2
								-.64	3
r								---	

Table 15. (continued)

Key		s	t	u	v	Line
	a	-.25	.06	-.28	-.01	1
		-.20	.09	-.11	-.30	2
65°C=horizontal line 1		-.06	.68	-.02	-.22	3
75°C=horizontal line 2						
85°C=horizontal line 3	b	.04	-.04	.43	.44	1
		-.14	.31	.15	.66	2
s=juiciness		-.76	.18	.44	.36	3
b=pH						
c=press fluid, total	c	-.18	-.26	-.19	.27	1
d=press fluid, serum		.53	.13	.18	-.27	2
e=press fluid, fat		-.58	.35	.12	-.07	3
f=fluid exuded, panel						
g=fluid exuded, total	d	-.45	-.34	-.37	-.48	1
h=WHC		-.05	-.19	.47	-.10	2
i=tenderness, chews		-.40	-.17	.11	.46	3
j=over-all acceptability						
k=cooking losses, total	e	.37	-.22	-.10	-.11	1
l=total moisture		-.13	.21	-.36	.08	2
m=tenderness, initial		-.05	.54	-.12	-.49	3
n=flavor						
o=shear, lateral	f	.45	-.45	.18	-.09	1
p=shear, medial		-.44	.04	.36	.22	2
Color difference, meat		.19	.03	-.08	-.08	3
q=Rd						
r=a-	g	.09	-.41	-.38	-.38	1
s=b+		.37	-.44	-.40	-.67	2
Color difference, fluid		-.05	-.13	.01	.03	3
t=Rd						
u=a-	h	.07	.16	.23	-.56	1
v=b+		.18	-.30	.55	.26	2
		.18	-.67	.30	.52	3
	i	-.36	.10	-.06	.01	1
		-.68	.17	.09	-.31	2
		-.31	.33	-.12	-.25	3

j	-.14	-.17	-.18	-.03	1
	-.28	.21	.18	.32	2
	-.16	.23	.16	.04	3
k	.07	-.65	-.26	-.12	1
	.18	.01	-.31	-.12	2
	.01	.17	-.41	-.60	3
l	-.28	.15	.13	-.19	1
	.36	-.64	.51	-.03	2
	.16	-.37	-.04	.26	3
m	-.18	-.09	-.05	-.10	1
	-.65	.33	.03	-.20	2
	-.52	.60	.06	-.12	3
n	-.16	-.42	-.37	-.56	1
	.10	.35	-.34	.11	2
	.17	.60	-.17	-.35	3
o	.47	-.10	.30	-.32	1
	.43	-.14	.14	.37	2
	.19	.43	.08	.31	3
p	.37	-.03	.38	-.34	1
	.55	-.24	.27	.54	2
	.07	-.12	.30	.29	3
q	.30	.50	-.35	.42	1
	.21	.26	-.07	.30	2
	.17	-.10	-.14	-.33	3
r	-.48	.01	.31	-.32	1
	-.51	-.31	.43	-.37	2
	-.59	-.04	.44	.38	3

Table 15. (concluded)

		s	t	u	v	Line
Key	s		.04	.03	.01	1
			-.43	.31	.01	2
65^{0}C=horizontal line 1			-.38	-.26	-.05	3
75^{0}C=horizontal line 2						
85^{0}C=horizontal line 3	t			.24	.40	1
				-.28	.37	2
a=juiciness				-.47	-.64	3
b=pH						
c=press fluid, total	u				-.18	1
d=press fluid, serum					.38	2
e=press fluid, fat					.75	3
f=fluid exuded, panel						
g=fluid exuded, total						
h=WHC						
i=tenderness, chews						
j=over-all acceptability						
k=cooking losses, total						
l=total moisture						
m=tenderness, initial						
n=flavor						
o=shear, lateral						
p=shear, medial						
Color difference, meat						
q=Rd						
r=a-						
s=b+						
Color difference, fluid						
t=Rd						
u=a-						
v=b+						

EFFECT OF THREE END POINT TEMPERATURES ON THE DONENESS AND PALATABILITY OF PORK LOIN ROASTS

by

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Heating fresh pork to 85°C has been the common practice to destroy Trichinella spiralis and prevent trichinosis in man. Regulations of the Meat Inspection Division, USDA (1960) state that pork must be heated to 58.3°C. Thus, the current practice seems to provide a greater margin of safety than necessary.

Anterior (A), middle (B), and posterior (C) sections of 12 pork loins were roasted at 350°F to study the effects of 3 end point temperatures (65, 75, 85°C) on the palatability and certain related characteristics of the longissimus dorsi (LD), and differences that occurred from the anterior to the posterior of the loin. A 3 x 3 Latin square was followed to cook 36 roasts.

Measurements on cooked LD included: scores for juiciness, tenderness, flavor, over-all acceptability, and color of fluid that exuded 45 min after the end point was attained; volume of press fluid and exuded fluid; water holding capacity (WHC); percentage total moisture; pH; Warner-Bratzler shear and Gardner Color-Difference values (Rd, a-, b+) for meat and exuded fluid. Rate of heat penetration and cooking time and losses were noted. Data for each factor were analyzed by analysis of variance, and when appropriate, least significant differences (P=0.05) were calculated. Shear values for medial and lateral positions in the LD were subjected to Student's t-test.

There was no marked organoleptic preferences for one end point, but 65 or 75°C resulted in significantly lower weight loss than 85°C. Section B retained more juice during roasting than A or C.

Juiciness, total moisture, and WHC decreased significantly with each 10°C increment in end point. Exuded fluid was significantly less at 85

than at 75 or 65°C, whereas press fluid and pH were not affected significantly. Section B was rated significantly higher than A or C in juiciness and total moisture, whereas volume of exuded fluid was significantly greater for C than for A or B. Differences among sections were not significant for WHC, press fluid, or pH.

Tenderness was not significantly affected by end point or medial or lateral position. However, lateral shear values were significantly lower for section C than for A or B. End points of 75 and 85°C produced significantly better flavor than 65°C, but the 3 sections were not significantly different. Over-all acceptability decreased slightly as end point increased and section C was significantly less acceptable than A.

Cooking time and losses (total and volatile) increased significantly with each increase in end point and drippings between 65 and 75 or 85°C. Total cooking time was significantly greater for section A than for B or C, but differences in min/lb were not significant. Total and volatile losses were significantly greater for A than for B and C, whereas drippings were significantly greater for A and C than for B. Differences in Rd values among end points were not significant for meat or exuded fluid. Meat a- values increased significantly between 65 and 75 or 85°C, whereas those for exuded fluid were significantly greater at 85 than at 65 or 75°C. Meat b+ values were significantly greater with each increment in end point, but there was no significant effect on b+ values or panel scores for exuded fluid. Section did not significantly affect color of meat or exuded fluid.